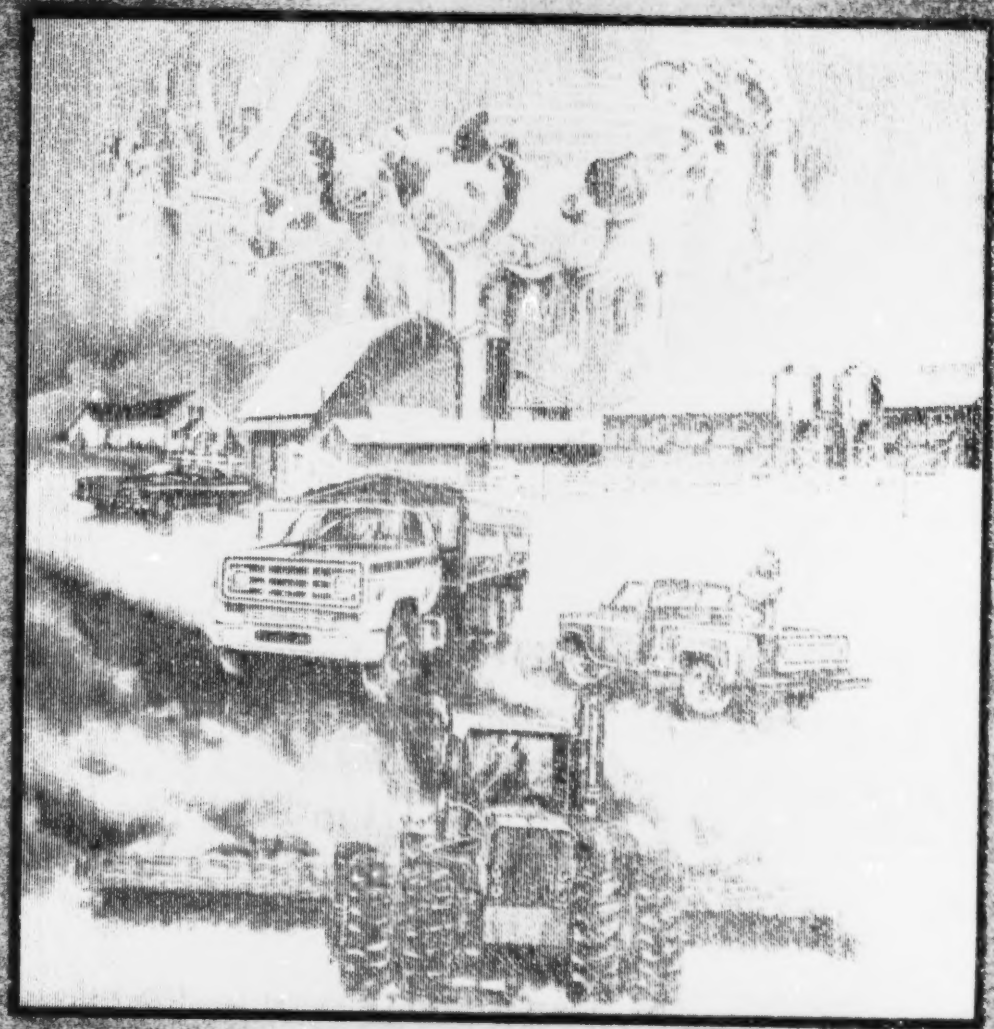

SASKATCHEWAN FARM ENERGY MANAGEMENT PROGRAM

Year 3 Report

SRC Technical Report
No. 157

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Year 3 Report

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Year 3 Report

by

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EXECUTIVE SUMMARY

The Farm Energy Management Program (FEMP) was a three year study of energy management and energy conservation demonstration on 22 Saskatchewan farms. The objectives of the program were to develop an energy management system applicable to any farm in Saskatchewan, to demonstrate various energy-conserving techniques, to develop an energy monitoring system for farms, and to assist in the transfer of efficient farm energy management to all Saskatchewan farmers.

A 'building block' system was developed for farm energy management. The system includes the following elements:

1) Use of fuel meters, logs and recording forms to determine where energy is being consumed on the farm (keeping close track of where fuel is being used was found to be a conservation tool in itself by identifying unexpected areas of high fuel use, e.g. personal transportation).

2) Evaluating and doing small, low cost, easy to do conservation measures.

3) Evaluating and implementing energy conservation measures which require significant dollar costs but offer attractive paybacks.

4) Evaluating farming practices and making changes which save energy, or use it more efficiently, e.g. reducing the number of tillage operations, or deep banding fertilizer.

5) Calculating the short-term and long-term benefits and costs of major changes in cropping systems and implementing testing and adoption of profitable changes. (This step in particular is linked to widespread activities to improve soil protection and fertility.)

Energy use was measured on all the farms to provide benchmarks for energy management and conservation. Energy use and distribution varied greatly between farms, indicating that energy management needs to be fitted individually to each farm. Fuel for transportation (cars and trucks) amounted to 42% of all the liquid fuels used on the farm, and most of the gasoline consumed. Car and truck fuel use thus offers major opportunities for improved energy management, and future improvements in fuel efficiency, as older vehicles are traded in for newer, more fuel efficient ones. Farms used, on average, 39-42 litres per hectare of gasoline and diesel fuel for all purposes in 1982 and 1983, very similar to the average fuel use measured for Saskatchewan farms in the federal farm energy use survey.

Energy used as fertilizers (i.e. an indirect use of energy) was 1.2 GJ (gigajoule) per cultivated hectare, very similar to the amount of energy used as liquid fuels for farm production purposes. This indicated that efficient use of fertilizer is as important as management of liquid fuel use for these farms. Recent statistics for the province indicate that annual fuel use is declining, as fertilizer use is increasing. The trends indicate that fertilizer will likely surpass liquid fuel as the principal energy use on Saskatchewan farms before very long.

Energy conservation measures in place on 20 of the FEMP farms at the end of 1983 were estimated to be saving approximately 360 GJ of energy per farm, worth over $3200 (1983 prices). Popular items included the following: — constructing new, energy efficient homes, — making minor energy retrofits to homes, —making more efficient use of tractors (e.g. matching equipment size to tractor power), — replacing older cars and trucks with more efficient new ones, — shifting to more energy efficient cropping practices (e.g. reducing tillage depth, using more soil tests, switching to deep banding of fertilizer, combining field operations, introducing minimum tillage systems).

Widespread adoption by Saskatchewan farmers of fuel saving methods such as replacing older, less fuel efficient cars and trucks with new ones, improving tractor operation as by the gear up - throttle down technique, and retrofitting farm homes to make them more energy efficient, could save up to $80,000,000 per year.

Measures to make energy used more efficient (e.g. more yield of wheat for the same investment in fertilizer) could also have a major economic impact. Widespread adoption of deep banding of nitrogen fertilizer, compared to broadcast methods commonly used now, was estimated to result in new income (i.e. income gain from higher yields of crop after deducting the cost of fertilizer and method of application) of approximately $110,000,000 annually.

In similar fashion, widespread adoption of the minimum tillage, 'stubble-in' method of growing winter wheat, compared to present common methods of

growing spring wheat on stubble, might generate up to $250,000,000 new income annually. This new income was calculated after deducting cash costs of fuel, fertilizer and herbicides. This new income was derived from a scenario in which winter wheat replaced all spring wheat now grown on stubble in Saskatchewan. About one half the fuel was required to grow a tonne of winter wheat, using minimum tillage methods, as to grow spring wheat using conventional tillage.

These dollar savings in fuel use, and income gains (in part due to more productive use of energy), are to be compared to net farm income (in 1982) of slightly over $1 billion for Saskatchewan farmers.

Several projects have been initiated by the private sector as a result of the Farm Energy Management Program. These include variable fertilizer rate methods, a conservation farming model, and a field efficiency computer program.

Technology transfer has commenced, and talks, seminars, and articles in the popular farm press have taken place, particularly in the last year.

Recommended follow-ups to the project include various methods of technology transfer to a much larger group of farmers, testing of the farm energy management system by other farmers, and the establishment and measurement of a number of new conservation demonstrations of different techniques, since successful demonstrations are considered a key component of effective technology transfer.

ACKNOWLEDGEMENTS

We gratefully acknowledge financing of the project by the joint Saskatchewan-Canada Agreement on Demonstration of Energy Conservation and Renewable Energy Technologies (CREDA). Energy, Mines and Resources (Canada) and Energy and Mines (Saskatchewan) were the joint administrators of the program. In particular, the following individuals participated in many meetings and helpful conversations about the project:

- Martin Wrubleski, Saskatchewan Agriculture (scientific authority for the project).
- Paul Gebhardt, Saskatchewan Agriculture.
- Jack Peck, Saskatchewan Agriculture.
- Dan McFadyen, Saskatchewan Energy and Mines.
- Floyd Wist, Saskatchewan Energy and Mines.

In addition to the above, C. McNeil (Energy, Mines and Resources) provided valuable suggestions and comments on the final reports.

We particularly thank the farm families involved with the project for their hospitality and cooperation on the many visits which we made to each of these farms. The names of the farmers who participated are given in Table 2.

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1. INTRODUCTION

The Farm Energy Management Program (FEMP) was initiated in August 1981 to develop and demonstrate energy-saving concepts for Saskatchewan farmers. This report summarizes the activities of the program to April 1984, and discusses opportunities for cost effective energy conservation and energy management on prairie farms.

Background

Energy is a major input cost to Saskatchewan farmers, both in *direct forms* as fuels and electricity, and in *indirect forms* as fertilizers and herbicides (Table 1). The Farm Energy Management Program was established to examine the impact of higher energy costs on Saskatchewan farms, and to review the potential for improved energy efficiency in agricultural production systems.

Objectives

Specific objectives defined at the beginning of the Farm Energy Management Program were:

1) To develop an energy management system applicable to any farm.

2) To demonstrate various energy-conserving techniques on Saskatchewan farms.

3) To develop an energy monitoring system to show the effects of conservation techniques on farm energy use.

4) To assist in the technology transfer of efficient farm energy management to all Saskatchewan farmers.

TABLE 1
FUEL AND FERTILIZER AS PART OF TOTAL FARMING EXPENSES IN SASKATCHEWAN (AGRICULTURAL STATISTICS, 1982).

Item	Expenses for All Farms (thousands of dollars)	Percent of Total Operating Expenses
Gasoline, diesel fuel and lubricants	366,056	15.6
Machinery repairs, etc	283,396	12.1
Fertilizer	187,191	8.0
Other crop expenses, e.g., herbicides	187,453	8.0
Feed	99,984	4.3
Other livestock expenses	35,549	1.5
Repairs to buildings	40,327	1.7
Electricity and telephone	47,812	2.0
Miscellaneous expenses	217,595	9.3
Taxes, farm rent, labour wages, interest on debt	876,940	37.4
Total operating expenses	2,342,303	
Total operating expenses and depreciation charges	3,046,068	
Total gross income (in 1982)	4,226,741	
Total net income	1,180,673	

2. METHODOLOGY

This section outlines the activities of the FEMP program during its first three years of operation.

Farmer Selection

Three criteria were used in selecting participants for the program:

1) innovative farmers who were good record keepers,
2) regional distribution throughout the study area, and
3) variety in types of farming enterprises.

Fig. 1 shows the locations of the 22 farmers in the program. Table 2 describes their farm size and operations.

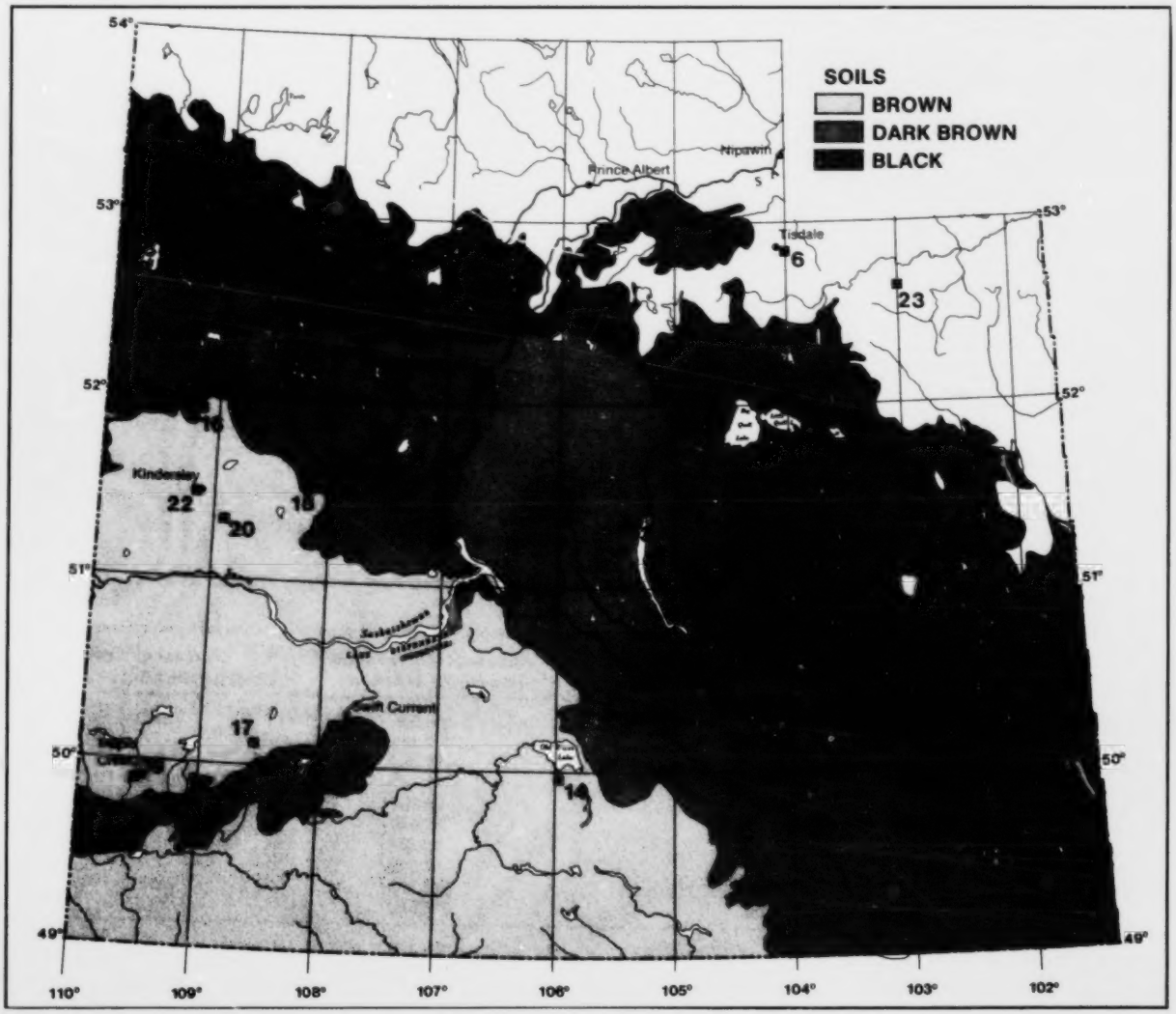


Fig. 1 Location of farmer participants in the Farm Energy Management Program.

Farm Energy Audits

Energy audits were conducted by visiting each farm cooperator to obtain information from his records and practical operating experiences. During Year I, an audit was made of individual farm inventories of equipment, buildings, livestock and land. In addition, data on crop management practises were obtained. Each farmer was subsequently supplied with an energy cost analysis for his farm which calculated the impact of the proposed National Energy Program Pricing Agreement (Fig. 2).

A detailed survey of field equipment operations (fuel use) and fertilizers and herbicides use (indirect energy), on a field by field basis, was carried out for the 1983 season. Energy consumption of specific crops, with respect to liquid fuels and total energy forms, was thereby determined.

Fuel Meters and Logs

In the spring of 1982 fuel meters were installed on all gasoline and diesel fuel storage tanks on the participating farms. A total of 82 meters were required. The meters selected were a dual-register type so that one register can be reset to zero for each refueling, while the other register records the total cumulative fuel volume dispensed (Fig. 3).

Along with each meter a waterproof log book (Fig. 3) was supplied to record fuel volumes, equipment type, and farming operation, at each refueling.

Data Collection

Cropping records and other production data were collected mainly by periodic farm visits. Similarly, heating fuel and electricity consumption were derived from farm accounts, based on invoices and receipts. Liquid fuel use logs were mailed by the farmers to the FEMP research team in Saskatoon. Missing data or doubtful entries were clarified by telephone conversations with the cooperators.

Data Analysis

Computer programs were written to compile and present the fuel log data in various formats. Liquid fuel use was sorted by farm operation (Table 3) and seasonal distribution (see Figure 5). The data was further segregated according to power equipment, or vehicle usage, in terms of total annual fuel use, consumption rate, and, where applicable, the use efficiency.

Individual field inputs and operations were summarized for each farm (Table 4). Energy conversions were

TABLE 2
LOCATION, TYPE AND SIZE OF THE FARMS STUDIED

Farm #	Name	Location	Farm Type	Cultivated area (ha)	Soil Zone
1	Christopherson	Weldon	Grain, Beef	571	Black
2	Sobkow	Calder	Grain and Hay, Beef	713	Black
3	Abrey	Imperial	Grain	504	Dk. Brown
5	McAllister	Regina	Grain	501	Dk. Brown
6	Rice	Tisdale	Grain and Hay, Beef	696	Black (Dk. Grey)
7	Bauml	Humboldt	Grain, Hogs	686	Black
8	Newport	Marsden	Grain	1219	Black
9	Taylor	Landis	Grain, Sheep	312	Dk. Brown
10	Howse	Pangman	Hay, Dairy	176	Brown
11	Daniels	Cochin	Grain and Hay	266	Black
12	Puetz	Humboldt	Grain and Hay, Beef	180	Black
13	Larson	Semans	Grain and Hay, Hogs	535	Dk. Brown
14	Robb	Mossbank	Grain	820	Brown
15	Slimmon	Heward	Grain	1730	Dk. Brown
16	Reynolds	Kerrobert	Grain	628	Brown
17	Connick	Gull Lake	Grain and Silage, Beef	345	Dk. Brown
18	Hanney	McGee	Grain	1246	Brown
19	Ahner	Maple Creek	Hay and Silage, Beef	121	Brown
20	Mickleborough	Eston	Grain	968	Brown
21	Burtney	Cudworth	Grain and Silage, Dairy	603	Black
22	McBain	Kindersley	Grain	518	Brown
23	Howse	Carragana	Grain	110	Black (Dk. Grey)

applied to indirect sources of energy use such as fertilizers and herbicides, to develop a profile of total energy expenditure per cropped hectare, and per tonne of grain produced. Fuel log data was used in conjunction with Saskatchewan custom rate figures to calculate energy used for specific crop production on a field-by-field basis.

Energy efficiency indices (L/ha, L/t; total GJ/ha, GJ/t) relevant to each farm's operation were determined to provide benchmark values for future comparison of other farms and operational changes.

Graphical summaries of total energy cost and distributions were prepared from the yearly data for each farm (Fig. 4).

Comparisons of energy use and costs on all farms were supplied to the cooperators for their own evaluations.

Technical Assistance

On-going technical consultation was made available to the farmer participants by telephone, mail and farm visits. This generally involved supplying energy conservation literature or contacts for specific sources of technical information, such as the National Research Council experts on low-energy home construction and the University of Saskatchewan researchers on 'gear-up-throttle-down' tractor operation.

Feedback

Annual seminars provided a forum for the farmers and researchers to compare their viewpoints on energy management in agriculture. Farmers gave the majority of the talks in the seminars. These meetings were particularly useful in providing guidance to the project.

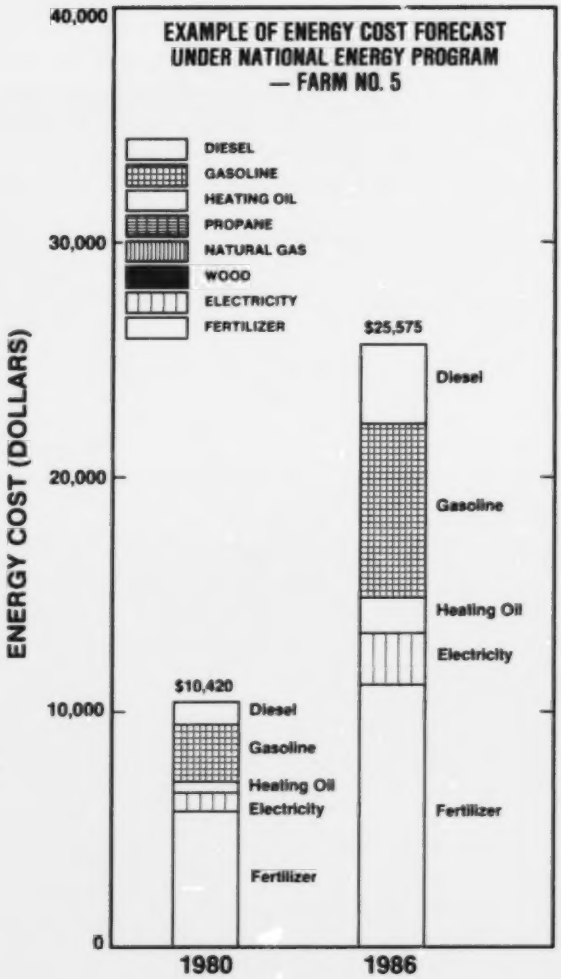
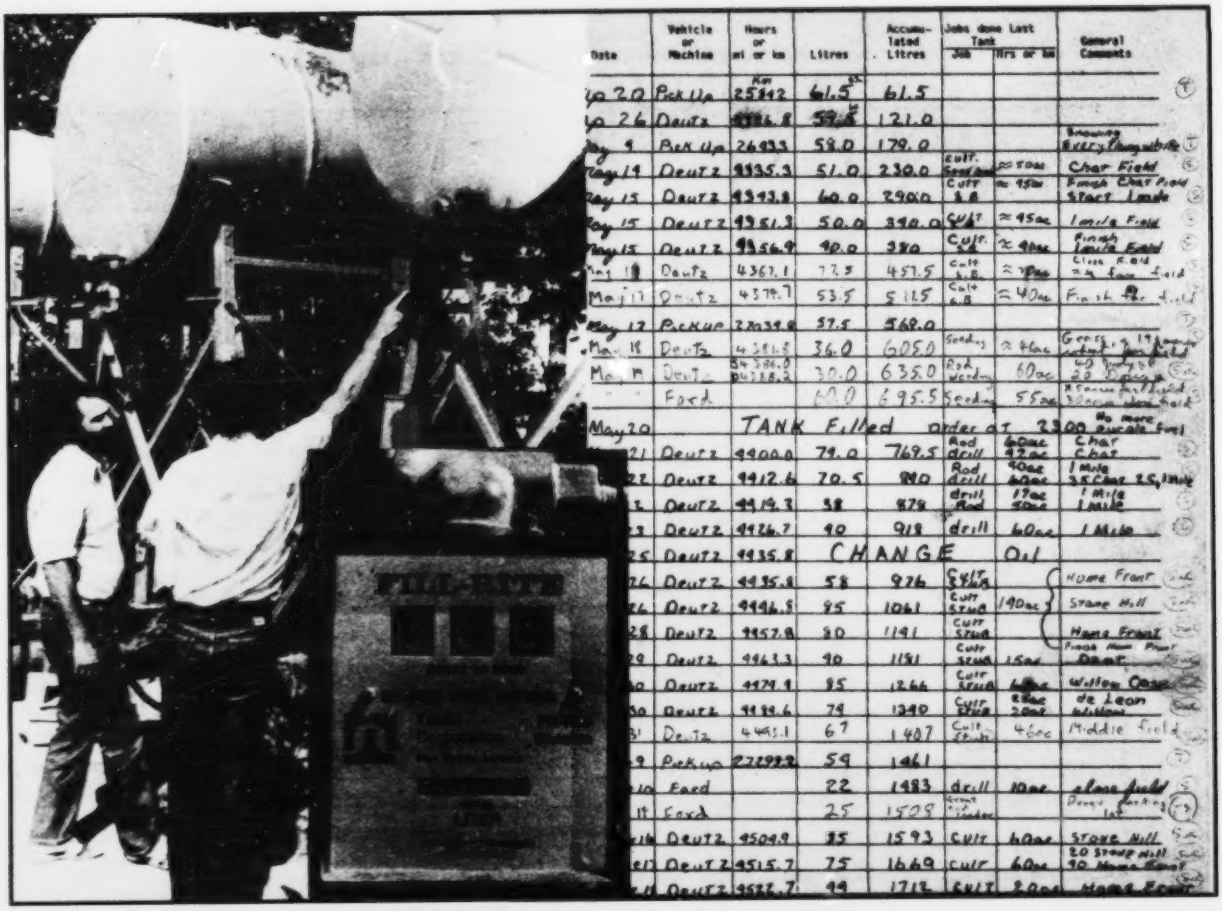


Fig. 2 Example energy cost forecast under the National Energy Program for farm no. 5.

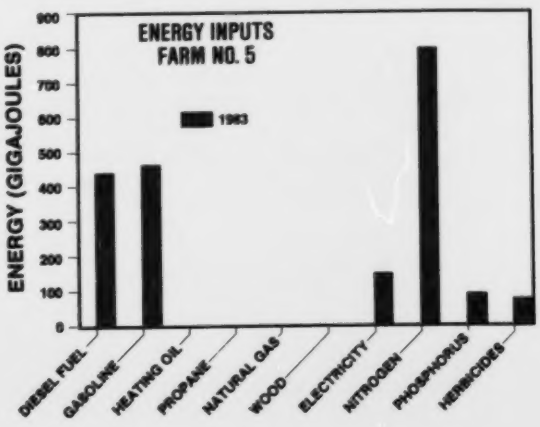
TABLE 3
LIQUID FUEL USE BY OPERATION, 1982 (EXAMPLE OF RESULTS)
Farm No. 5

Operation	Diesel Fuel		Gasoline		Total
	(L)	(GJ)	(L)	(GJ)	(GJ)
Crop miscellaneous	149	6	106	4	9
Farmstead			307	11	11
Feed	66	3	33	1	4
Harvest & hauling	3279	127	2016	70	196
Seeding	3484	135	665	23	158
Summerfallow & weed control	4092	158	33	1	159
Transportation			3142	108	108
Used by others	96	4	125	4	8
Total	11166	432	6427	222	654



Date	Vehicle or Machine	Hours or mi or km	Litres	Accumulated Litres	Jobs done Last Tank: Job	Jobs done Last Tank: Hrs or ac	General Comments
Apr 20	Pick Up	25942	61.5	61.5			
Apr 26	Deutz	4386.8	59.5	121.0			
May 9	Pick Up	26933	58.0	179.0			Seeding Early Barley with Air Seeder
May 14	Deutz	9335.3	51.0	230.0	Cult. Seed Bed	≈ 50ac	Char Field
May 15	Deutz	9393.8	60.0	290.0	Cult 5.8	≈ 95ac	Finish Char Field Start Imule
May 15	Deutz	9451.3	50.0	340.0	Cult 5.8	≈ 95ac	Imule Field
May 15	Deutz	9506.9	40.0	380	Cult. 5.8	≈ 90ac	Finish Imule Field
May 16	Deutz	4367.1	77.5	457.5	Cult 5.8	≈ 90ac	Close Road ≈ 4 from field
May 17	Deutz	4379.7	53.5	511.5	Cult 6.8	≈ 40ac	Finish [illegible] field
May 17	Pickup	27039.8	57.5	568.0			
May 18	Deutz	4391.8	36.0	605.0	Seeding	≈ 40ac	Grass [illegible]
May 19	Deutz	84386.0 84388.2	30.0	635.0	Rod Weeding	60ac	40 Barley 20 Oats
	Ford		60.0	695.5	Seeding	55ac	5 Corn 30 Grain
May 20		TANK Filled					No more diesels fuel
21	Deutz	9400.0	79.0	769.5	Rod drill	60ac 42ac	Char Char
22	Deutz	9412.6	70.5	840	Rod drill	40ac 40ac	1 Mile 35 Close 25, 1 Mile
23	Deutz	9419.3	58	898	drill Rod	17ac 50ac	1 Mile 1 mile
23	Deutz	9426.7	90	918	drill	60ac	1 Mile
25	Deutz	9435.8	CHANGE			Oil	
26	Deutz	9435.8	58	976	Cult Seed		Home Front
26	Deutz	9446.5	85	1061	Cult Seed	190ac	Stone Hill
28	Deutz	9457.8	80	1141	Cult Seed		Home Front
29	Deutz	9463.3	90	1151	Cult Seed	150ac	Finish Home Front Start [illegible]
30	Deutz	9479.9	95	1246	Cult Seed	60ac	Walton Close
30	Deutz	9489.6	79	1340	Cult Seed	80ac 20ac	de Leon Walton
31	Deutz	4493.1	67	1407	Cult Seed	46ac	Middle Field
9	Pickup	27299.2	54	1461			
10	Ford		22	1483	drill	10ac	close field
19	Ford		25	1508	Grass Seeding		Finish Seeding Start [illegible]
16	Deutz	9504.9	85	1593	Cult	60ac	Stone Hill
17	Deutz	4515.7	75	1669	Cult	60ac	20 Stone Hill 40 Home Front
21	Deutz	9525.7	99	1713	Cult	80ac	Home Front

Fig. 3 Keeping track of fuel. Fuel meters were installed on all gasoline and diesel fuel storage tanks on the participating farms to help record their use of fuel. A log book was supplied to record fuel volumes, equipment type and farming operations of each refueling.



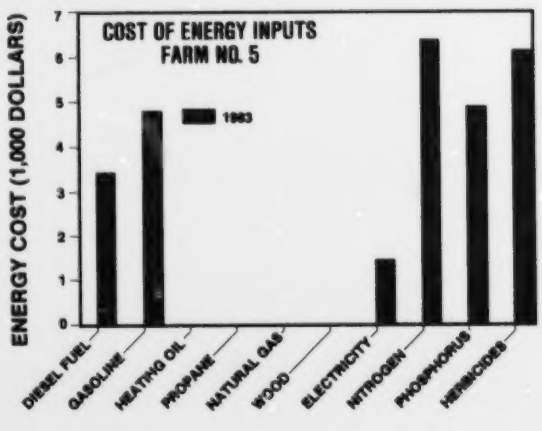


Fig. 4 Energy costs for farm no. 5, 1983.

TABLE 4
FARM NO. 5 — CROP PRODUCTION PRACTICES — 1983

Crops	On Fallow (acres)	On Stubble (acres)	Field Operations Machine	Width (ft)	No.	Tractor	Fuel D	Fuel G	Fertilizer Type	Fertilizer Rate (lb/ac)	Herbicides Type	Herbicides Rate (oz/ac)	Yield (bu/ac)	Remarks
Spring Wheat	415		discers	30	1X	2390	•		11-51-0	40	Avadex	16	35	Seed, fertilize with Avadex in one operation sp swather used to open fields only.
			harrows	60	2X	1070	•							
			sprayer	75	1X	1070	•				Banvel	1.5		
			swather	16	1X	s.p.		•						
			swather	24	1X	1070	•				MCPA	4.0		
			combine		1X	2390	•							
			trucking					•						
Spring Wheat		362	discers	30	1X	2390	•		11-51-0	40 (on all)			35	
			fert. spr.		1X	1070	•		34-0-0	147 (on 266 ac)				
			harrows	60	2X	1070	•		46-0-0	109 (on 96 ac)				
			sprayer	75	1X	1070	•							
			swath sp	16	1X	s.p.		•			2-4-D amine	6.0 (on 180 acres)		
			swather	24	1X	1090	•				Banvel	1.5 (on 185 acres)		
			combine		1X	2390	•				MCPA	4.0 (on 185 acres)		
			trucking					•						
Flax #1		82	discers	30	1X	1070	•		11-51-0	25			16	
			harrows	60	1X	1070	•							
			har/pack	45	1X	1070	•							
			spray	75	1X	1070	•				Poast	(14 L on 21 ac)		
			swath	16	1X	s.p.		•			(wild			
			swath	24	1X	1070	•				oats)			
			combine		1X	2390	•							
			trucking					•						
Flax #2			discers	30	1X	1070	•		11-51-0	20	Avadex	16	16	
			fert.		1X	1070	•		34-0-0	147				
			har/pack	45	1X	1070	•							
			swath	16	1X	s.p.		•						
			swath	24	1X	1070	•							
			combine		1X	2390	•							
			trucking					•						
Flax #3 (on 44 ac of sloughs)			cult (HD)	22	1X	2390	•		Nil		Nil		Nil	Sloughs worked in fall of '82 when dry. — seeded in spring '83 but flooded out in summer.
			harrow	60	1X	1070	•							
			DD drill	14	1X	Oliver88		•						
			har/pack	45	1X	1070	•							
Lentils		54	discers	30	1X	2390	•		11-51-0	25				Seed/fert. one operation
			harrow	60	1X	1070	•							
			har/pack	45	1X	1070	•				Senco	.17 L/ac.		
			spray	75	2X	1070	•				Poast	1.6 L/ac.		
			swath	16	1X	s.p.		•					900 lbs.	
			combine		1X	2390	•						on 54 ac.	
			trucks					•						
Fallow Operations	295		cult (HD)	22	2X	2390	•							
			rodweed	36	2X	2390	•							

3. RESULTS

Farmer Response

All participants in the project were enthusiastic about the value of energy management on the farm. Many farmers were surprised at their fuel consumption, particularly in the transportation category. An important effect of the fuel metering program was that farmers became more energy-conscious in equipment selection and operations. In other words, the simple installation of fuel meters may be a significant conservation measure.

Many farmers also stated that they had not previously considered nitrogen fertilizer as an energy input to crop production. This concept led to considerable interest in legume crops in areas with sufficient precipitation.

Farmers were generally receptive to any ideas which could increase production per dollar of energy input. They were wary of any conservation idea that might decrease production.

Farmers spent much time discussing loss of soil fertility and spread of salinity on their farms. Frequent topics at seminars were new cropping systems to minimize loss of soil fertility, and increase soil productivity. As a response to this, a number of demonstrations (being done by other researchers) of new cropping systems were analyzed to determine the energy efficiency, and to aid FEMP farmers in decision making.

Energy Use On The Farms

The energy used on the FEMP farms in the form of liquid fuels (direct energy use) and in the form of fertilizers (indirect energy use) varied widely between individual farms. Nonetheless, it was possible to divide the farms, and farm energy use, into different categories, so they could be compared with each other, and so the results could be compared with other studies.

LIQUID FUEL USE. Fuel use was divided into:

1) PRODUCTION: fuel used for annual and perennial crop production, summerfallowing, hauling grain to the country elevator, hauling fertilizer, operations associated with livestock production (such as harvesting, baling and transporting hay, grinding feed for hogs, handling and hauling manure), and operations associated with land improvement such as clearing land and picking rocks.
2) TRANSPORTATION: fuel used for cars and half-ton trucks, regardless of whether used for personal purposes or farm business (except for a few cases where light trucks hauled heavy loads).
3) OTHER FARM USE: fuel used for other farm purposes such as garden tractors, all-terrain vehicles, snowmobiles and lawn mowers. This was a very small category on most farms.

Pronounced seasonal peaks in diesel fuel used were found, whereas gasoline use (i.e., transportation use) was much more evenly distributed throughout the year (Fig. 5).

Cars and light trucks accounted for 29% of all liquid fuel used. Heavy trucks used a further 12% of liquid fuels. The total transportation sector, including one airplane, represented 42% of all liquid fuel use. This sector accounted for 87% of all gasoline used on all the farms.

Use of fuels in cars and light trucks was quite closely correlated to total farm size for most farms. For several farms where transportation fuel use was higher than average, there were two or more families living on the same farm. For most farms, there was a good correlation between farm size (total) and fuel use in cars and light trucks, and an average of 0.41 GJ of fuel

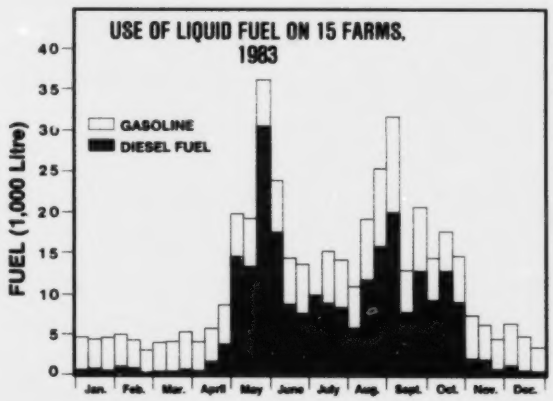


Fig. 5 Seasonal use of liquid fuel on 15 farms in 1983.

energy was used (in 1982) per hectare of farm area. This is equivalent to about 12 litres of gasoline per hectare.

Production equipment (tractors, self-propelled swathers, combines and sprayers) used just under 57% of all the fuel used on the farms. Of the 41 litres of fuel per hectare (total farm area) used for all purposes on all farms, 24 litres were used by production equipment (mobile field equipment). The vast majority of this was diesel fuel. Of the total farm use of liquid fuel, diesel was 58% and gasoline 42%.

Farms varied greatly in energy use and in the distribution of energy use between different forms of direct (fuel and electricity) and indirect energy (fertilizer and herbicides). Fig. 6 shows the distribution of energy use, on a per-cultivated-hectare basis, for all farms studied in 1983. These results suggest that each farm should approach energy management on an individual basis, although various general principles would apply.

To give some benchmarks for comparison with other farms, average fuel and fertilizer use was calculated for all the farms, although it was recognized that there were large differences between individual farms (as shown in Fig. 6). To detect any differences in fuel use between different types of farms, farms were separated into crop farms (wheat, barley, oilseeds, pulse crops and hay), and mixed farms which produced animals (beef or hogs) as well as annual crops and hay.

Fuel use by the different types of farms was examined in two ways; fuel use for crop production per cultivated hectare, or total farm use per whole farm hectare (including pasture). Average fuel use, and the range between farms, is shown in Table 6.

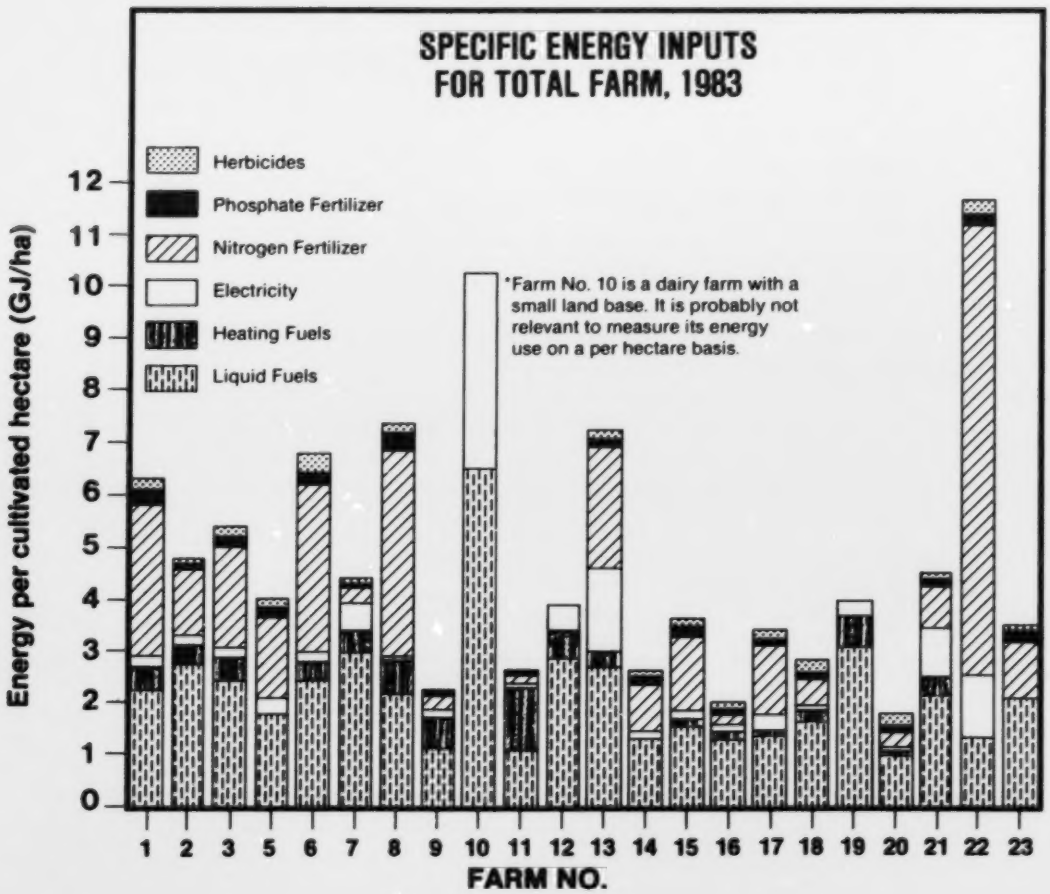


Fig. 6 Specific energy inputs (total farm) for 22 farms, 1983.

TABLE 5
FARM SIZE AND DISTRIBUTION BETWEEN CROPS AND SUMMERFALLOW IN 1982

Farm Type	Average Farm Size (ha)	Cultivated Area (ha)			
		Total	Annual Crops	Perennial Crops	Summerfallow
All Farms[1] (19)[2]	800	705	455	19	231
Crops Only Farms (9)	1020	982	626	4	352
Crops & Livestock Farms (10)	603	455	301	32	122

[1]Excludes one dairy which had a small land base and purchased much of the feed needs.

[2]Number of farms in category.

TABLE 6
FUEL USE FOR CROP PRODUCTION AND FOR ALL FARM ACTIVITIES INCLUDING PERSONAL TRANSPORTATION

Farm Type	Fuel Use (litres of diesel fuel equivalent)	
	Production Operations Per Cultivated Hectare	Total Farm Activities (Production, Transportation and Other) Per Hectare of Total Farm Area
All Farms in 1982 (19)[1]	31 (13-48)[2]	39 (14-66)[2]
:Crops Only Farms (9)	26 (18-39)	35 (24-50)
:Crops and Livestock Farms (10)	35 (13-48)	42 (14-66)
All Farms in 1983 (20)	31 (16-48)	42 (13-73)

[1]Number of farms in category

[2]Range between all farms included

TABLE 7
COMPARISON OF FERTILIZER AND FUEL ENERGY USED ON FEMP FARMS

Year	Energy embodied in fertilizer (GJ/cultivated ha)	Energy in liquid fuels used for production (GJ/cultivated ha)
1982	1.2	1.2
1983	1.3	1.2

FERTILIZER USE. Average fertilizer use, per cultivated hectare, was similar in 1982 and 1983. Nitrogen fertilizer rates of application were 16.9 kg/ha in 1982 and 17.7 kg/ha in 1983. Phosphate (P_2O_5) rates of application were 12.6 kg/ha in 1982 and 13.0 kg/ha in 1983. There were great differences between farms in rates of fertilizer application, reflecting differences in soil zone, intensity of crop production, and crops grown.

Table 7 demonstrates that indirect energy in fertilizer, i.e. the energy required as raw materials and process energy to manufacture fertilizer, equalled the energy in liquid fuels used for production.

The implication of these results is that efficient use of fertilizers is as important for farm energy management as is management and conservation of liquid fuels.

In a separate approach to energy use, an extensive survey was carried out on all FEMP farms in 1983 to analyze energy use on a crop-by-crop and field-by-field basis. Fuel use was calculated from the unit operations described by the farmer for each field. Heavy truck fuel use was calculated only for on-farm use, e.g. hauling grain from the field to farm storage. Yields of all crops were obtained so as to calculate energy use per tonne of product. Results are shown in Tables 8 and 9.

Use of fuel, fertilizer and herbicide was more closely correlated with the length of rotation (i.e. the % cropped area) than with the soil zones.

While herbicides were a minor energy input, they were a major dollar cost, compared to fuel. Fertilizer became the dominant energy and dollar cost as the intensity of crop production increased.

TABLE 8
ENERGY AND DOLLAR COSTS OF FUEL, FERTILIZER AND HERBICIDES FOR GROWING ANNUAL CROPS ON FEMP FARMS, 1983

Intensity of Crop Production as % of Cultivated Land in Crops	No. of Farms	Energy Consumption per Cultivated Hectare								
		Fuels (d.f.e.)[1]			Fertilizers			Herbicides (active ingredients)		
		(L)	(GJ)	($)	(kg)	(GJ)	($)	(kg)	(GJ)	($)
50-60	9	22	.86	8	28	.55	9	0.5	.11	10
60-70	5	24	.92	9	69	1.55	20	0.5	.14	12
70-100	5	32	1.24	12	103	2.76	33	1.1	.21	19

[1]Calculated from unit operations reported by farmers. Fuel use derived from Saskatchewan Agriculture Custom and Rental Rates, 1982. d.f.e. = diesel fuel equivalent on-farm fuel use only.

TABLE 9
ENERGY INPUTS AND PRODUCTIVITY MEASURES FOR ANNUAL CROPS ON FEMP FARMS, 1983

Intensity of Production as % of Cultivated Land in Crops	No. of Farms	Energy Inputs			Productivity Measures					
					Actual Crops (1983)			Wheat Equivalent[2]		
		Fuels (d.f.e.)[1] (L/ha)	Total Energy (GJ/ha)	Energy Cost ($/ha)	Fuels (L/t)	Total Energy (GJ/t)	Cost ($/t)	Fuels (L/t)	Total Energy (GJ/t)	Cost ($/t)
50-60	9	22	1.5	26	19	1.2	21	19	1.3	22
60-70	5	24	2.6	41	20	2.2	34	20	2.2	34
70-100	5	32	4.2	64	21	2.6	40	19	2.4	37

[1]d.f.e. = diesel fuel equivalent. On-farm fuel use only.

[2]Different crops were prorated based on yield relative to wheat to obtain one measure of productivity relative to yield on all farms.

Conservation Measures Implemented

Many of the 22 Farm Energy Management Participants, either prior to, or during its three year operation, adopted various energy conservation measures. The group was reasonably well informed and responsive to energy saving techniques, in particular those of a no cost - low cost nature. However, energy considerations were not always the dominant motive for making some of the changes. As a general rule, practices that increased energy efficiency tended to be readily accepted as long as they were consistent with the overall efficiency of the farm operation.

Demonstrations of different types of energy conservation, and improvements in energy efficiency of use, were measured. These examples were coupled with interviews with farmers to measure the degree of use of different conservation techniques. Total energy savings on all the farms were calculated from the results of the interviews, from the results of specific demonstrations on farms, and from data given in a recent publication by one of us (N.E. Jensen, 'Saving Energy and Dollars on the Farm', to be published by Agriculture Canada).

Checklist interviews with 20 FEMP farmers indicated many alterations in energy management, the majority made in the three year period of the project. Table 10 summarizes energy conservation measures implemented by farmers in the project. The total annual energy saving achieved to date by the FEMP farmers is estimated to be 7,175 GJ. At an average energy cost of $9.00/GJ the dollar savings equal about $65,000 per year among the 20 farmers interviewed. This represents an average saving of $3,250 per farm.

TABLE 10
ENERGY SAVING MEASURES IMPLEMENTED ON FEMP FARMS.

No. of Farms	Measure Implemented	Energy Saving (GJ per year)
Farmstead		
5	constructed new, energy-efficient homes	250
1	undertook a major energy-efficient home retrofit	50
13	increased insulation of existing homes	130
17	installed weatherstrip and sealed cracks	170
16	lowered home furnace thermostat by 1°C (=2°F)	160
18	reduced hot water usage	90
5	lowered hot water temperature to 50°C (122°F)	25
17	eliminated unnecessary home and outbuilding lighting and/or used lower wattage bulbs	85
8	reduced farm yard lighting	40
12	purchased energy-efficient appliances	35
11	reduced vehicle block heater use to 2-3 hours daily	25
7	constructed or retrofitted shops/barns, incorporating energy efficient designs	140
3	installed barn heat exchangers	100
7	used wood for shop or supplementary home heating	140
12	shaded, painted and/or installed pressure relief valves on fuel tanks to reduce evaporation losses	120
Tractors		
17	improved equipment size match to available tractor power	425
14	used gear-up-throttle-down operation for light loads	200
14	reduced idling time	140
7	adjusted ballast for optimum slippage range	100
1	purchased radial tires for improved traction	10
3	replaced tractors with more fuel efficient models	150
Cars and Trucks		
6	reduced unnecessary travel	90
11	lowered driving speed by 8 km per hour	160
3	installed VHF radios in trucks and tractors for better travel management	45
6	replaced vehicles with more fuel efficient models	400
Crop Production		
18	reduced tillage depth	450
2	combined existing equipment field operations	230
9	removed obstacles for improved working field patterns	175
2	switched to single pass air seeders	150
3	harvested by straight combining	200
13	used soil tests for fertilizer application requirements	500
6	adopted custom or self-operated anhydrous ammonia deep banding	800
1	banding manure	100
4	used legumes as a nitrogen source	720
3	started to grow winter wheat under a reduced tillage system	150
6	reduced the number of summerfallow operations in normal crop rotations	280
3	experimented with full or partial chemical weed control to reduce tillage in summerfallowing	140
	Total	7,175

Demonstrations of Energy Savings

LIQUID FUEL AND HEATING OIL SAVINGS. Demonstrations of various fuel saving techniques were carried out on FEMP farms testing different methods to save fuel in tractors, in cars and light trucks, and in homes (space heating). Examples of results are shown below:

1) **Reduced fuel use in tractors by eliminating tillage operations.** One tillage operation was eliminated for summerfallowing on Farm #5 (Regina area). Stubble was not worked in the fall, as used to be the common practice. While the number of summerfallow operations varied from year to year depending on moisture conditions and subsequent weed growth, on average the farmer reduced summerfallowing by one operation per year.

   In 1983 there were 119 hectares in summerfallow on Farm #5. Based on elimination of one tillage operation with a heavy duty cultivator, fuel savings were calculated to be:

   (4.65 L/ha) x (119 ha) = 553 L

   At a cost of 36.6¢/L, total savings were $202. Based on fuel log and meter records, savings by this technique were 4% for tractor diesel fuel.

2) **Diesel fuel savings by efficient operation of farm tractors.** For light loads, which require less than 65% of the tractor's power, tractors can be throttled back to 70 to 80 percent of rated RPM and shifted up to a higher gear, resulting in significant fuel savings. Improvements in fuel economy of up to 36% have been demonstrated elsewhere by shifting up and throttling back under these light load conditions.

   The University of Saskatchewan (Agriculture Engineering Department) conducted demonstrations and tests on 16 tractors on Saskatchewan farms as a separate CREDA project. Arrangements were made for a number of FEMP farms to be included in these tests.

   The percentage savings varied widely amongst different tractors. On average, 15% savings were measured for light load conditions, by using the gear up - throttle down technique. Based on observations of tractor use, and the opinion of many of the farmers involved in the tests, the gear up - throttle down mode of operation could be used one-third of the total operating time. Estimations and measurements were that the average tractor worked 350 hours per year and used 28 litres of fuel per hour. The average farm was calculated to have 2.5 tractors.

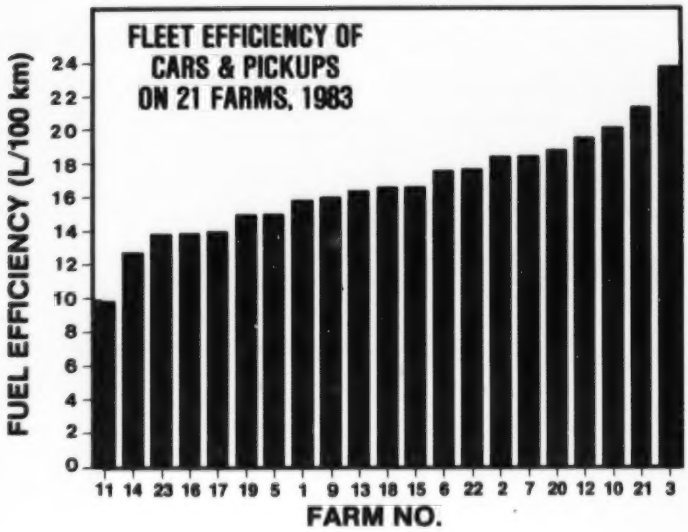


Fig. 7 Fleet efficiency of cars and pickups on 21 farms, 1983.

Fuel savings per farm were estimated to be

(2.5 tractors) x (350 h/tractor) x (28 L/h) x (15/100) x (1/3) = 1224 L

At 36.6¢/L diesel fuel, annual savings per farm would be $448.

3) **Reduced fuel use for transportation.** The fuel efficiencies of cars and light trucks were analyzed for 21 of the FEMP farms. Average fuel efficiencies per farm for cars and light trucks are shown in Figure 7. The fuel efficiencies ranged from 10.0 -23.9 L/100 km, with an average per farm of 17.1 L/100 km.

   It was calculated that if the average fuel efficiency per farm could be improved to the efficiency of the farm that performed best, a 41% savings in fuel would result. Based on total fuel use in 1983 in all cars and light trucks of 216,450 L, the fuel thus saved would be 90,000 L per year. At 39¢/L, the fuel savings would total $35,000 per year for all the 21 farms, or an average annual saving per farm of $1,667.

4) **Savings in fuel oil needs for home space-heating.** A major retrofit of an older farm home was done on Farm #12 in the Humboldt area of Saskatchewan. Prior to the retrofit, the house was found to be in need of major structural repairs to walls and roof. The decision was made to add energy efficiency improvements to the house at the same time as the major replacements of siding and roofing were being done. THe HOTCAN computer program was used by SRC's Energy Conservation in Housing group to aid the farmer in determining the most cost effective retrofit measures. The program was also used to calculate the overall savings on space-heating energy consumption.

   The measured fuel savings were 43.8%, corrected for a small increase in floor area of the house after the retrofit. This represents a reduction in fuel oil use of 1150 litres annually, worth $400. The total cost of the retrofit was $22,170 plus labour of the farmer. However, only the extra costs for insulation and other energy efficiency improvements were assigned to energy related costs. These costs were calculated to be $2,910. Thus the payback period would be $2910 ÷ $400 = 7.3 years.

INDIRECT ENERGY SAVINGS IN CROP PRODUCTION: Savings in Nitrogen Fertilizer Energy, and Improvements in the Productivity of the Use of Fuel and Fertilizer. Major changes are occuring in crop production methods in western Canada that could lead to substantial improvements in the productivity of the use of fuel and fertilizer, e.g., less fuel and fertilizer to produce a tonne of wheat. The major reasons for these changes are not energy related, but are related to goals of improved soil protection, improved productivity of soils and water, and reduction in soil salinity.

It was observed frequently at seminars and in conversations, that farmers were becoming increasingly aware of declines in soil fertility through too much summerfallowing, and of losses in soil nitrogen from not replacing as much as was exported in the grain.

Farmers are starting to test various methods to remedy these situations; e.g.:

1) using legumes in cropping systems to replace some of the nitrogen (N) exported in grain,
2) increasing the amount of stubble cropping, i.e. reducing the amount of summerfallowing,
3) growing winter wheat instead of spring wheat as a stubble crop, using a new system involving minimum tillage and snow trapping in standing stubble (more efficient use of fuel, fertilizer and snow moisture),
4) using more N fertilizer, but using it as efficiently as possible.

Results of demonstrations and farm trials (both on FEMP farms and on other farms in Saskatchewan) were analyzed for their energy efficiency improvements and energy savings. In a number of cases, the FEMP team analyzed the results of existing demonstrations of new or improved cropping methods, established by crop and soil scientists. This eliminated duplication of effort and provided additional useful results for both studies. Highlights of results are given below:

1) **Alfalfa plowdown to provide N fertilizer energy via biological fixation.** A University of Saskatchewan demonstration (part of the Farm Lab demonstration program) on a farm in the grey wooded soil zone, was analyzed (see Table 11). Over 4 GJ/ha of N fertilizer energy was saved. From FEMP results, this is about *3 times* the energy in fuel that would be required to grow and harvest the wheat crop.

2) **Deep banding of nitrogen fertilizer to improve efficiency of use of fertilizer energy.** Deep banding of fertilizer has been shown to result in more efficient use of nitrogen fertilizer than broadcasting methods. Sixteen trials carried out by others on farmers' fields across western Canada were analyzed for their energy effects. Results of demonstrations with urea are shown in Table 12.

   Even when the extra fuel and equipment costs for deep banding were taken into account, this method of fertilizer application gave the most efficient use of energy.

3) **Increased energy efficiency by applying the optimum rate of fertilizer.** A demonstration to show the optimum rate of fertilizer application was carried out on one of the FEMP farms (#5) as part of the University of Saskatchewan Farm Lab program. Different rates of urea were deep banded into standing stubble in the fall and wheat planted the next spring. The FEMP team analyzed the energy effects, shown in Table 13.

TABLE 11
NITROGEN FERTILIZER SAVED BY GROWING WHEAT AFTER ALFALFA PLOW-DOWN

	Wheat crop effects after: Alfalfa plow-down	Wheat	
N fertilizer added (kg/ha):	0	0	60
Yield of wheat following alfalfa or wheat (t/ha)	2.4	1.2	2.4
N fertilizer energy used (GJ/ha)	0	0	4.4
Income minus N fertilizer costs ($/ha)	415	207	368

TABLE 12
INFLUENCE OF DEEP BANDING NITROGEN FERTILIZER (UREA) ON YIELD, INCOME AND ENERGY EFFICIENCY OF WHEAT PRODUCTION

	Rate and method of fertilizer application		
	Check	Broadcast	Deep Banded
Rate of N application (kg/ha)	0	84	84
Yield of grain (t/ha)	1.8	2.3	2.5
Income from wheat minus costs of urea and application ($/ha)	301	335	357
Efficiency of nitrogen fertilizer use per tonne of wheat (kg/t)		37	32
Fertilizer and fuel energy used[1] per tonne of wheat (GJ/t)		2.7	2.6

[1]Includes the small amount of fuel energy needed for application of fertilizer: 0.07 GJ/ha for broadcasting, 0.18 GJ/ha for deep banding

TABLE 13
EFFECT OF DIFFERENT RATES OF UREA DEEP BANDED INTO STANDING STUBBLE ON THE YIELD OF WHEAT: DEMONSTRATION OF ENERGY EFFECTS.

Rate of N application (kg/ha)	Yield of wheat (t/ha)	Income from wheat minus fertilizer cost ($/ha)	N fertilizer energy used (GJ/ha)	N fertilizer energy used per tonne of wheat (GJ/t)
60	2.4	377	4.4	1.8
90	3.5	538	6.5	1.9
120	3.5	543	8.7	2.5
135	3.2	464	9.8	3.1

Too high rates of urea application led to lower yields and dollar returns, and a substantial waste of N fertilizer energy. These results stress the need for adequate soil testing.

4) **Hidden energy costs of summerfallowing.** Recent experiments by Agriculture Canada at Swift Current and by the University of Saskatchewan were analyzed to demonstrate the hidden energy costs associated with leaching of nitrates or volatilization of nitrates, as nitrous oxide or nitrogen, from summerfallowed land. The results are shown in Table 14.

   To get an idea of the magnitude of these potential energy losses, they have been expressed as diesel fuel equivalents. Thus to replace the nitrogen fertility loss in 150-200 kg of nitrogen would require as much embodied energy to manufacture urea fertilizer as is contained in 280-375 litres of diesel fuel. This is about *10 times* the amount of diesel fuel needed to seed, grow and harvest a crop of wheat.

5) **'Stubbled in' winter wheat: an energy efficient crop and crop production system employing zero or minimum tillage to reduce fuel use.** Six farms (including one FEMP farm, #22) were studied to measure yields and energy used to grow winter wheat compared to spring wheat. Farmers used Norstar variety of winter wheat with improved winter hardiness over other varieties. Winter wheat was sown into standing stubble of a previous crop using minimum tillage seeding methods to maintain a protective uniform snow cover for winter protection and to reduce fuel consumption. Results from a farm in the Quill Lake area (black soil zone) are shown in Table 15. This farmer has grown winter wheat successfully for 8 years using the stubble-in method. Spring wheat is grown with conventional tillage methods. Differences in fuel use should be similar to what the average farmer in Saskatchewan would expect. The same amount of fertilizer was used for both crops.

   Winter wheat appears to offer significant opportunities for increased income and efficiency of use of liquid fuel and other energy inputs, if grown with the appropriate technology.

   Based on results from this farm, fuel consumption per hectare was a third less with the minimum tillage system used for winter wheat. The fuel used to grow a tonne of winter wheat was about half that required for spring wheat, reflecting the different tillage systems and the inherent yield advantage of winter wheat over spring wheat.

TABLE 14
RATES OF NITROGEN FERTILITY LOSS FROM SUMMERFALLOWED LAND. DEMONSTRATION OF THE MAGNITUDE OF THE ENERGY LOSS.

Mechanism of nitrogen fertility loss	Loss of N fertility per year		Energy required annually to replace lost N fertility
	(kg/ha)	(GJ/ha)	(Expressed as litres of diesel fuel equivalent)
Leaching below root zone in a wet year	150-200	10.9-14.5	280-375
Volatilization as nitrous oxide or nitrogen	~ 10	0.73	19

TABLE 15
COMPARISON OF WINTER WHEAT AND SPRING WHEAT AS STUBBLE CROPS (2nd CROP) IN TERMS OF INCOME AND ENERGY USE.

	Winter wheat	Spring wheat
Gross return[1] ($/ha)	382	316
Energy costs (fuel, fertilizer, herbicides) ($/ha)	85	119
Gross return minus cost of fuel, fertilizer and herbicides ($/ha)	297	197
Liquid fuel use (L/ha)	22.9	34.2
Total energy use (GJ/ha)	7.2	7.8
Productivity measures:		
Fuel use (L/t)	9.3	17.8
Energy use (GJ/t)	2.9	4.1
Energy cost ($/t)	35	62

[1]Minus seed used

Discussion of Results and Comparisons With Other Studies

Results of the FEMP study were compared with statistics on agricultural energy use in the province and with several recent studies on energy use in Canadian agriculture.

The Saskatchewan energy flow accounts give data on the energy used in major Saskatchewan industries and activities, including agriculture. Results are based on provincial and federal statistics. Gasoline use includes a large portion of that fuel's consumption in cars used for farm business. Another recent study, the

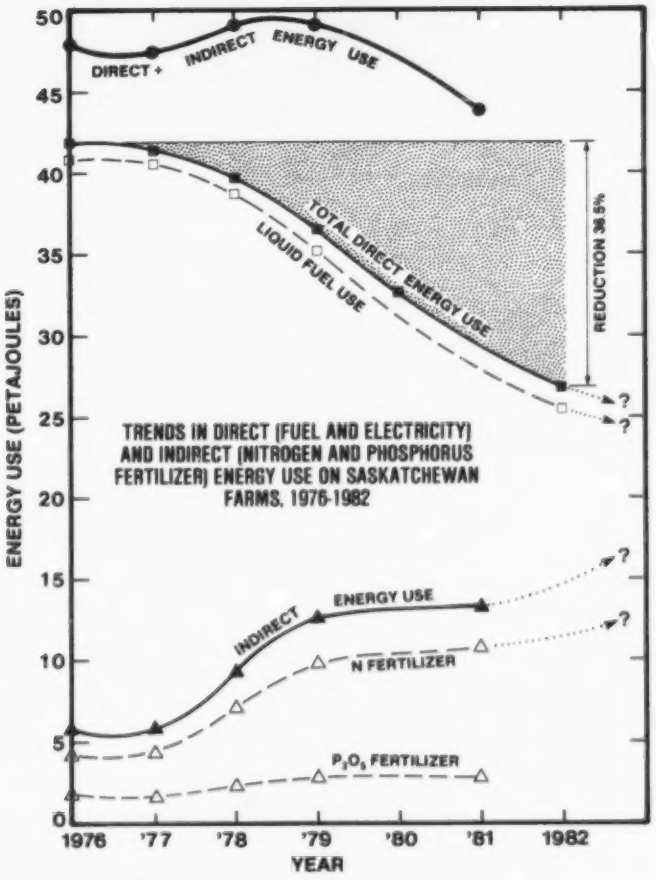


Fig. 8 Trends in direct (fuel and electricity) and indirect (nitrogen and phosphorus fertilizer) energy use on Saskatchewan farms, 1976-1982.

federal Farm Energy Use Survey, reported that 87% of gasoline was apportioned to farm business use, the rest being used for non-business purposes.

Fig. 8 shows trends in energy use on all Saskatchewan farms since 1976, based on the Saskatchewan energy flow accounts, and recent statistics on fertilizer use (indirect energy). There has been a substantial drop in direct energy use (mainly liquid fuels), and a substantial rise in nitrogen fertilizer use.

Some of this increase in nitrogen fertilizer use may be associated with attempts to counteract the declining fertility of prairie soils, well documented by soil scientists. This decline in soil fertility has been in part attributed to losses associated with the widespread practice of summerfallow, and in part to the fact that the amount of export of nitrogen in the form of grain has greatly exceeded the amount of nitrogen returned to the soil in the form of fertilizer or nitrogen fixing crops. Remedies suggested for this situation have included reducing the amount of summerfallow, increasing the percent of land in crop, and increasing the rates of nitrogen fertilizer application.

It was very evident at FEMP seminars that farmers were as concerned with soil protection, improvement in soil productivity, and in cost effective methods to improve yields, as they were in saving energy. This is confirmed by the recent shifts in energy use in agriculture (see Fig. 8). Savings in liquid fuel energy appear to have been shifted to increased use of fertilizers, in part at least, so as to improve soil protection, improve soil productivity, and restore lost soil fertility.

Fig. 9 shows trends in gasoline and diesel fuel use, based on two studies. These are the Saskatchewan energy flow accounts, and a study by Gayton* based on provincial statistics on the use of marked fuel (i.e., purple gasoline and farm diesel fuel). The main effect appears to be a substantial drop in gasoline, probably most pronounced in cars, since unmarked gasoline

*See reference list at the end of the report.

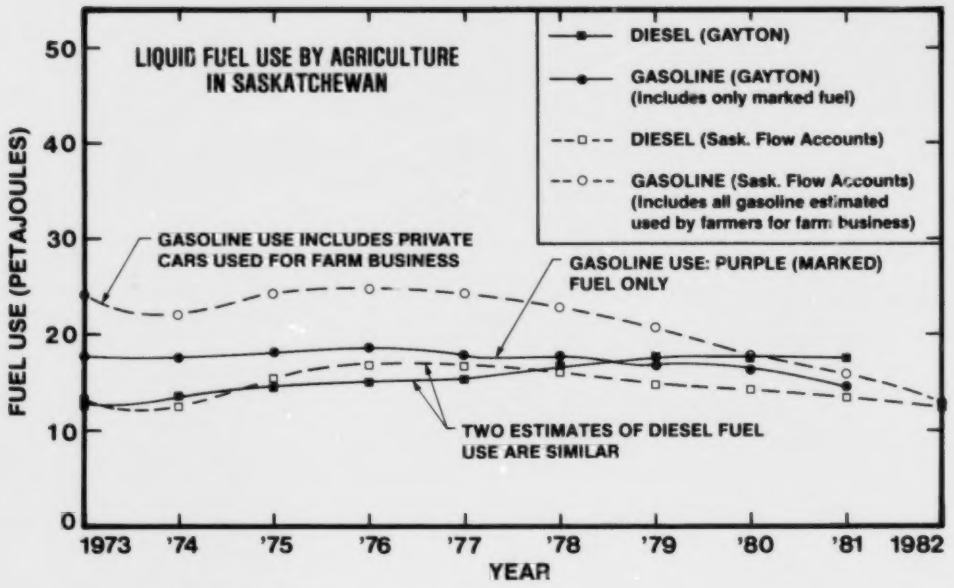


Fig. 9 Liquid fuel use by agriculture in Saskatchewan.

use appears to have dropped faster, and more, than marked fuel.

Another study, by Hopper of the University of Manitoba, on energy used in prairie wheat production, measured a 20% drop in liquid fuel use between 1977 and 1981. Similar to the other studies, the main decrease observed was in gasoline consumption. This was attributed to a switch to more fuel efficient diesel powered machinery, a combination of elimination of field operations, and a general curtailment in transportation activities.

The federal Farm Energy Use Survey was based on questionnaires and interviews with 7,000 farmers across Canada. About 3,000 of these were from the prairies. Energy use in 1981, and conservation measures being done, were recorded. Based on an average farm size of 423 hectares, about 38.6 litres per hectare of fuel (diesel fuel equivalent (dfe)) were used for all purposes, of which 36.1 L/ha were designated for farm purposes.

Significant conservation measures (being done by more than 10% of prairie farmers) included:

1) combined or eliminated field operations
2) reduced distance travelled
3) increased vehicle and machinery maintenance
4) purchased larger and/or more efficient machinery
5) added insulation to farm home
6) lowered temperature of water heater
7) converted farm building heating system to alternate fuel

Inspection of Table 10 of this report will indicate that many of the FEMP farmers are using these conservation measures also.

A comparison of the FEMP study with the others was made (Table 16) on the basis of total fuel use per

TABLE 16
COMPARISONS OF TOTAL FUEL USE ON FARMS

	Total liquid fuel use (litres of diesel fuel equivalent per hectare of total farm area)	
Study	**1982**	**1983**
Farm Energy Management Program:		
All Farms	39	42
:Crops Only Farms	35	38
:Crops and Livestock Farms	42	47
Farm Energy Use Survey (1981)	39	
Gayton Study of Saskatchewan Farms (1981)	34[1]	
Saskatchewan Energy Flow Accounts (1982)	32[1]	

[1]Estimated from data on farm business use

hectare of the total farm area. Where studies gave only the portion of fuel used for farm business, the ratios between total liquid fuel use, and fuel used for farm business, reported by the Farm Energy Use Survey, were used (87% of gasoline, 99% of diesel fuel for farm business).

Farms in the FEMP study appear to be similar in liquid fuel use to the farms in the Farm Energy Use Survey, although our average farm size was larger (800 ha vs. 423 ha). Seven FEMP farms had two or three families living on the same farm. This is higher than provincial statistics would suggest (2.8 people per farm), and could bias our sample to higher than average transportation fuel costs.

Putting It All Together: A Building Block Approach To Farm Energy Analysis and Conservation Action

Different methods, forms, and trials were evaluated, in order to develop techniques for monitoring energy use on farms, and in aiding in the testing and adoption of energy conserving farm practices.

As these concepts were evaluated, it was realized that they could be made into a general package for evaluating energy use on a farm and in planning and implementing conservation changes. Each technique could be used by itself to monitor energy use, or a particular aspect of it (e.g., an innovative farming practice being tested on one field) and to plan and carry out conservation actions. The techniques could also be combined in different ways depending on a farmer's interest.

The resulting general system for farm energy management is shown in Figure 10. The system contains five main elements, each of which could be used separately, or in combination:

1) **Audit energy use on the farm.** The experience of the FEMP program is that audits themselves frequently become a conservation tool, by helping people become aware of the magnitude of particular energy uses. A number of farmers were surprised to see how much fuel was used by cars and light trucks. As a result, various conservation actions are being taken, e.g., purchasing more efficient half-ton trucks.

2) **Evaluate and do small, inexpensive, easy energy conservation measures.** Most of the FEMP farmers have put many of these techniques into action already. Checklists prepared for FEMP list common ones: a new Agriculture Canada book will give more details. We believe that this is the place many farmers should start (coupled with an audit program) in implementing an energy management program.

3) **Analyze and implement energy conservation measures which require significant investment but offer attractive returns.** Pay back times, cash flow, and financing methods are all important factors in making decisions about what to do and how to pay for it (for example, doing a major retrofit on a house). A simple computer program has been developed to calculate the best way to finance this type of conservation actions. Provision has also been made in this program to include cost savings from use of government grants. (Fig. 11)

4) **Improve energy efficiency in farm production practices.** Based on conservation measures used by FEMP farmers, many actions are being taken. Examples are: reducing depth of tillage, reducing number of tillage operations, gear up - throttle down tractor operation, deep banding nitrogen fertilizer, testing snow management methods. Record keeping systems were developed to follow changes in a particular vehicle, or a particular field. Coupled with use of fuel tank meters, or on-board fuel monitors on vehicles, these should allow particular changes to be monitored and evaluated.

5) **Calculate short-term and long-term economic effects of major changes in cropping systems.** A TI-59 program was designed and tested with several farmers. This calculates the effects of new systems such as more continuous cropping with snow management, minimum tillage and straight combining, compared to more conventional grain production systems. Expected benefits to soil fertility could also be built into this program. A larger, more flexible system is needed which could be used with micro-computers with visual display screens (for example, the types that will soon be in regional offices of the provincial Department of Agriculture). These programs could be used to interface energy efficiency and conservation actions with techniques for new and improved farming systems, designed to provide better protection of soils and improved productivity of soils and available water.

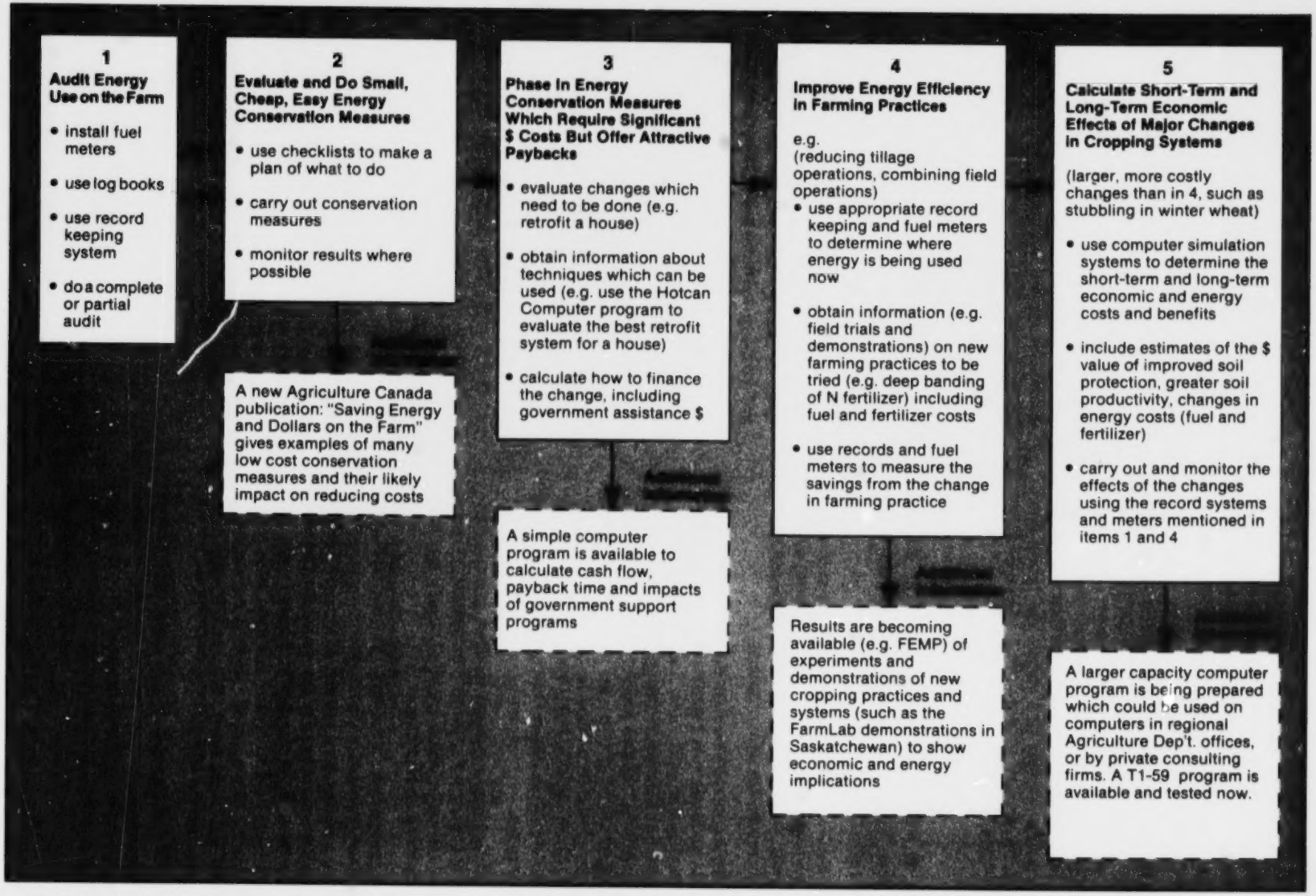

1
Audit Energy Use on the Farm
• install fuel meters
• use log books
• use record keeping system
• do a complete or partial audit
2
Evaluate and Do Small, Cheap, Easy Energy Conservation Measures
• use checklists to make a plan of what to do
• carry out conservation measures
• monitor results where possible
A new Agriculture Canada publication: "Saving Energy and Dollars on the Farm" gives examples of many low cost conservation measures and their likely impact on reducing costs
3
Phase In Energy Conservation Measures Which Require Significant $ Costs But Offer Attractive Paybacks
• evaluate changes which need to be done (e.g. retrofit a house)
• obtain information about techniques which can be used (e.g. use the Hotcan Computer program to evaluate the best retrofit system for a house)
• calculate how to finance the change, including government assistance $
A simple computer program is available to calculate cash flow, payback time and impacts of government support programs
4
Improve Energy Efficiency in Farming Practices
e.g.
(reducing tillage operations, combining field operations)
• use appropriate record keeping and fuel meters to determine where energy is being used now
• obtain information (e.g. field trials and demonstrations) on new farming practices to be tried (e.g. deep banding of N fertilizer) including fuel and fertilizer costs
• use records and fuel meters to measure the savings from the change in farming practice
Results are becoming available (e.g. FEMP) of experiments and demonstrations of new cropping practices and systems (such as the FarmLab demonstrations in Saskatchewan) to show economic and energy implications
5
Calculate Short-Term and Long-Term Economic Effects of Major Changes in Cropping Systems
(larger, more costly changes than in 4, such as stubbling in winter wheat)
• use computer simulation systems to determine the short-term and long-term economic and energy costs and benefits
• include estimates of the $ value of improved soil protection, greater soil productivity, changes in energy costs (fuel and fertilizer)
• carry out and monitor the effects of the changes using the record systems and meters mentioned in items 1 and 4
A larger capacity computer program is being prepared which could be used on computers in regional Agriculture Dep't. offices, or by private consulting firms. A T1-59 program is available and tested now.

Fig. 10 A system for farm energy management (steps 1 to 5 can be done separately or in different combinations).

Capital Cost	$6000	Revenue first year	$923
Deduct.Startup Costs	$0	Revenue Increase per yr (%)	8.0
Inputs (exp) first yr	$0	Loan Term (yrs)	15
Input Increase per yr (%)	0.0	Loan Interest Rate	12.50
Income Tax Rate (%)	5	Loan (1 = Ammort., 2 = Dim. Bal.)	1
General Inflation Rate	8	Loan Payments per year	12
C.C.A first year (%)	5.0	Study Scope (1 = all, 2 = part)	2
C.C.A. 2nd year (%)	5.0	Study Term In Years	15
C.C.A. other years (%)	5.0	Starting Year of Study	1
CCA Type (1 = dim, 2 = orig)	1	Downpayment	$0

Year	Inputs	Revenue	Principal	Interest	Taxes	Cashflow	Total CF	CCA
1	0.00	923.00	145.57	741.85	-5.94	41.53	$41.53	300.00
2	0.00	996.84	164.84	722.57	-0.54	109.96	$151.49	285.00
3	0.00	1076.59	186.67	700.74	5.25	183.92	$335.41	270.75
4	0.00	1162.71	211.39	676.03	11.47	263.83	$599.24	257.21
5	0.00	1255.73	239.38	648.04	18.17	350.15	$949.39	244.35
6	0.00	1356.19	271.07	616.34	25.39	443.39	$1392.78	232.13
7	0.00	1464.69	306.97	580.44	33.19	544.09	$1936.87	220.53
8	0.00	1581.86	347.62	539.80	41.63	652.82	$2589.69	209.50
9	0.00	1708.41	393.65	493.77	50.78	770.22	$3359.90	199.03
10	0.00	1845.08	445.77	441.64	60.72	896.95	$4256.85	189.07
11	0.00	1992.69	504.80	382.61	71.52	1033.75	$5290.61	179.62
12	0.00	2152.10	571.64	315.77	83.28	1181.41	$6472.01	170.64
13	0.00	2324.27	647.34	240.08	96.10	1340.75	$7812.77	162.11
14	0.00	2510.21	733.06	154.36	110.09	1512.71	$9325.47	154.00
15	0.00	2711.03	830.12	57.29	125.37	1698.25	$11023.72	146.30
End of run		Total Cash Flow (present value)			$5310.55			

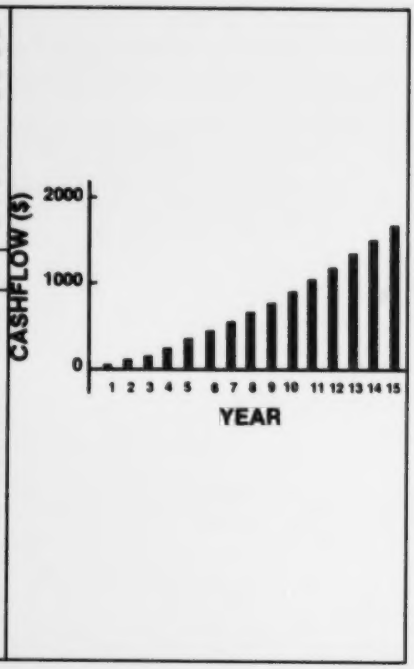


Fig. 11 Cash Flow Analysis: The additional added $6,000 capital cost of upgrading the design of a new house to low energy standards from conventional construction is compared to future energy savings. An annual inflation factor of 8% has been assumed for the energy price. The $6,000 extra cost was amortized over 15 years and a marginal tax rate of 25% was assumed, with one quarter of the house costs allocated to farm expenses.

4. POTENTIAL FARM ENERGY SAVINGS IN SASKATCHEWAN

Many of the energy management techniques demonstrated in this project could be implemented on any farm in Saskatchewan. Following are estimates of some of the major energy savings which could be achieved with application of simple and proven technology demonstrated in the Farm Energy Management Program:

Reduce Tillage Operations

Most FEMP farmers reduced tillage by at least 1 operation per year. Applied to 10,000,000 hectares of cultivated land in Saskatchewan, this could save about 45,000,000 litres of diesel fuel per year, worth over $17,000,000 per year. The percent of farmers doing this already is greater than 10%.

Gear Up/Throttle Down Tractor Operations

This is a simple procedure which costs nothing. It could save about 5 litres of fuel per hour for many underloaded field operations. If 60,000 tractors operated in this mode for 50 hours per year the fuel savings would be 15,000,000 litres of diesel fuel, worth about $5,500,000 per year. Another estimate, by the University of Saskatchewan, predicted potential savings of up to $29,000,000 per year, based on 116 hours per tractor of gear up - throttle down operation, and varying degrees of adoption to all tractors.

Improve Transportation Efficiency

Older cars and pickup trucks common on farms are notorious gas guzzlers. Several FEMP farmers demonstrated that careful vehicle selection can significantly cut fuel consumption. A 30% reduction applied to all farmers in Saskatchewan was considered quite possible over the next 5 years as older vehicles are replaced by new ones. Based on total gasoline used on farms, the potential savings are over 100,000,000 litres of gasoline, with a value of $38,000,000 per year, based on 1983 farm gasoline prices.

Upgrade Farm Homes

Replacement or retrofitting of a typical older farm home can result in annual heating energy savings of at least 50 GJ. Applied to 60,000 farm homes the potential annual savings equal 3,000,000 GJ. Based on FEMP results and the federal farm energy use survey, a considerable portion (say 25%) of these savings has already been achieved. Assuming 2,250,000 GJ still remains to be saved, and assuming a cost of $9/GJ for heating oil, would give a potential saving of about $20,000,000 per year.

Legumes in Crop Rotation

Future increases in legumes in cropping systems have been assumed to come primarily from green manure use of species such as sweet clover. Research studies are underway at a number of locations (University of Saskatchewan, Agriculture Canada) to integrate legumes with snow management to counteract moisture losses associated with older methods of using green manure crops. Based on research results, a nitrogen fixation benefit of 50 kg per hectare (released over several years) seemed likely in the less dry regions of the province. If 1,000,000 hectares can in future be placed in green manure legume crops, about 50 million kg of N would be fixed. If this replaces urea, then the annual savings would be 3,650,000 GJ, worth about $30,000,000. Further contributions might also come from expansion in the area planted to pulse crops such as lentils and field peas, and in production of soybeans adapted to prairie climates.

Other benefits from green manure crops could include increases in soil organic matter and help in control of soil salinity. The total economic benefit might be considerably higher than the figure associated just with nitrogen fixation benefits.

Deep band nitrogen fertilizer to improve the efficiency of use

Less nitrogen fertilizer (4.9 kg N) (see table 12) was used to grow a tonne of wheat if the fertilzier (e.g. urea) was deep banded rather than broadcast. Applied to production of 5,000,000 tonnes of wheat, the savings would be 24,500,000 kg of N. As urea N this would represent a savings of 1.78 million GJ of energy, worth $14,700,000. However, more wheat is produced from the *same* investment in fertilizer, by the use of deep banding. Extra income by this

approach (after deducting the costs of fertilizer and application) is estimated to be $22/ha, or $110,000,000 if applied to 5,000,000 hectares.

Grow winter wheat by 'stubbling-in' to standing stubble

If Saskatchewan's present 2,500,000 hectares of stubble wheat crop were to be shifted from traditional spring wheat varieties to winter wheat, using proven 'stubble-in' practices, at least 28,000,000 litres of diesel fuel would be saved. This would be an effective saving of $10,000,000 per year.

From a previous table (Table 15), winter wheat yielded about $100 per hectare more income after deducting fuel, fertilizer and herbicide costs than did spring wheat, based on results from a farm growing both crops. Thus the greater income from 2,500,000 hectares in winter wheat could be as high as $250,000,000 (this figure includes the $10,000,000 fuel saving). For many farmers, this shift to growing winter wheat with minimum tillage methods ('stubble-in' method) might require new equipment (e.g. a new seed drill). The computer program devised for calculating major changes in cropping systems (Fig. 10) could be used to estimate all costs and benefits.

The amount of nitrogen fertilizer required would probably increase over present amounts used for spring wheat. However, it is worth noting that two of the farmers studied obtained substantial yield advantages of winter wheat over spring wheat with the same rate of N fertilizer applied to grow each.

Potential income effects of energy c r · tion and productivity improvements

Table 17 gives an overall picture of the maj·r savings and new income (*net* to energy relat· ·d of fuel, fertilizer and herbicides). It should b that these savings frequently involve some investment, e.g. to retrofit a house, to purcl more fuel efficient car, buy a new seed drill, to s a new cropping system such as stubbled-in · wheat. The methods described in the building approach to energy conservation (Fig. 10) s allow individual farmers to plot an investment app· to these considerable new savings.

TABLE 17
INCOME EFFECTS OF WIDESPREAD ADOPTION OF ENERGY CONSERVATION MEASURES AND IMPROVEMENTS IN ENERGY EFFICIENCY OF USE FOR SASKATCHEWAN FARMS

Examples	$ per year for Sask. farm·
Savings in liquid fuels and heating oil	up to 80,000,000
Green manure legume crops	up to 30,000,000
Deep banding of N fertilizer	up to 110,000,0C
'Stubble-in' winter wheat	up to 250,000,0C
Total	up to 470,000,0C
For comparison; farm income in 1982	= $4,227,000,000 (gro = $1,180,000,000 (ne

5. TECHNOLOGY TRANSFER

As shown before, the implementation of energy management technology on Saskatchewan farms offers major opportunities for energy savings. Technology transfer of FEMP results to other Saskatchewan farmers has been initiated by the following methods:

Seminars

Two seminars were conducted to give all FEMP participants an opportunity to report their experiences to the farm press, regional extension engineers and other extension personnel. These were excellent forums for exchange of information and publicity for the project. In addition, technical papers about the project were presented at a number of farm and extension conferences.

Farm Press

Farm reporters were invited to the seminars. This resulted in several articles about the project in farm magazines. Reporters liked the direct access they had to the farmers in the program so they could write their stories with a human interest element.

Extension Bulletins

One major bulletin (see lists of reports) describing the project was produced and distributed to all Agricultural Representatives and Regional Farmstead Engineers. Additional bulletins on specific energy management topics are in a draft stage of preparation. Subjects of bulletins include:

- Energy Use and Potential for Conservation on Saskatchewan Farms
- Fuel Use for Transportation on Saskatchewan Farms and Opportunities for Conservation
- Use of Fuel Meters and Fuel Keeping Records for Energy Management on Saskatchewan Farms
- Energy Costs of Sloughs and Potholes
- Using Air Photos for Farm Management
- Traditional versus Conservation Cropping Systems — the Farm Management Decision

6. SPECIAL PROJECTS

Interaction among researchers in the FEMP project led to a number of novel ideas for better energy management on the farm. The first four of these concepts are under further development by private corporations.

Aerial Photographs for Energy Management

In the summer of 1982 all project farms were photographed from the air by Prairie Agri-Photo Ltd., using infrared film. A presentation was made to the farmers describing how these photographs can be used to identify crop production problems, such as fertilizer and herbicide misses, drainage problems, and variations in soil productivity. A number of the project farmers expressed interest in continued testing of this technique.

Variable Fertilizer Applications

Farm West Management Ltd. initiated a project to test the potential benefit of varying the fertilizer rates to match the variation in existing nutrient levels throughout a field (Fig. 12). This concept is being evaluated in more detail under an Agriculture Canada research contract, and has led to creation of a new corporation for its commercialization.

Conservation Farming Computer Model

Two farmers in the project assisted in the testing of a FarmWest computer simulation model which calculates the economic impact of converting a farm to continuous cropping from a traditional crop-fallow

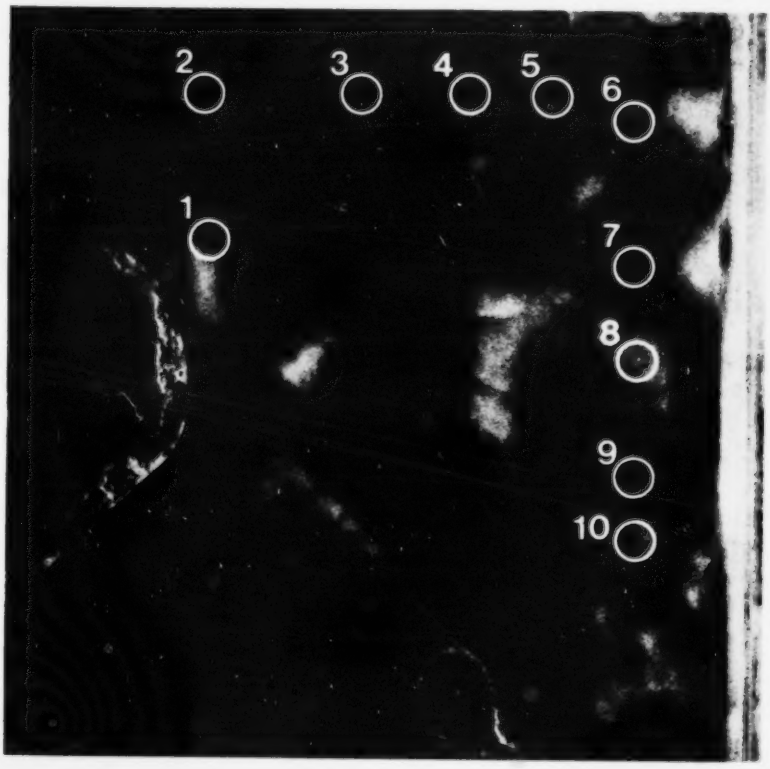


Fig. 12 An aerial photograph, taken before the crop came up, showed varying shades of grey (knolls lighter and hollows darker) – which were found to be closely correlated to the soil organic matter, nitrogen, and phosphorus. This aerial photo was used to map the different rates of fertilizer needed on the field. The net economic benefit to the farmer on this quarter section of applying the variable rate of fertilizer would be $1,700 or $26.20 per hectare ($10.60 an acre).

rotation. Further work is underway to refine and test this program.

Continued studies are planned to extend the model to test other new cropping systems, such as 'stubbled-in' winter wheat.

Field Efficiency Computer Model

Jensen Engineering Ltd. has initiated a project to develop a computer program to evaluate field efficiencies from aerial photographs of a given farm. The proposed system will allow a farmer to 'work' his fields by interactive manipulation of a microcomputer digitizing system. The computer will calculate the total distance travelled and time required for various field working patterns. It will be particularly valuable in calculating the costs of farming around field obstructions. A short bulletin on this subject has been prepared as part of the FEMP results.

Analyses of Demonstrations of New Cropping Systems

Various demonstrations of new cropping systems for Saskatchewan are underway as part of the University of Saskatchewan FarmLab project. The new cropping systems being demonstrated on Saskatchewan farms are designed to "maximize productivity and maintain high soil quality through water efficient farming practices". Deep banding of nitrogen fertilizer, snow management, minimum tillage, use of winter wheat, and use of legumes are examples of factors being tested in these demonstrations.

Four of the FEMP farmers are participants in the FarmLab demonstration project. Initial results from two of these farms, plus those from other farms, were analyzed for the energy effects, e.g., more efficient use of fertilizer energy, inclusion of legumes in rotations.

In addition, research results on new cropping systems from Agriculture Canada, University of Saskatchewan and United States Department of Agriculture in Montana were analyzed for their energy conservation or improved efficiency potential.

Initial results are reported in the Year 3 Background Report (R-711-B-84).

Substantial increases in crop yields, with improved efficiency of use of energy, appear possible by use of many of these new cropping systems. Further analyses are planned as more years of data accumulate from these demonstrations.

Results of these demonstrations will provide useful information for the Conservation Farming Computer Model (mentioned previously) to help farmers evaluate energy efficient new cropping systems.

Analyses of Cropping Systems

New forms were developed for analyzing energy use and energy productivity on a field and crop basis. Farms were analyzed by: crop (e.g. wheat), cropping rotation (e.g. wheat grown on summerfallow), and soil zone.

Results are presented in the year 3 background report.

The results provide:

1) a baseline for farmers planning changes,
2) a method for farmers to see where energy is going in a particular cropping system, and
3) baseline data for use in computer programs such as the conservation farming computer model.

Not surprisingly, fertilizer and herbicides increased in significance as the percent of cultivated land in crop increased. The previous section in chapter 3 titled "Energy Use on the Farms" gives some of the highlights of this study.

7. CONCLUSIONS

The Farm Energy Management Program has identified a number of important aspects of energy use and energy conservation in agriculture:

CONCLUSION 1: An energy management system has been developed which is believed to be applicable to most farms in Saskatchewan. The system has five components which can be used by themselves, or in various combinations to set up a fuel monitoring system, to make simple energy conservation changes, and to plan and implement major conservation options.

CONCLUSION 2: Various conservation techniques have been tested and put in place by the farmers. Changes already in place as of the end of 1983 are estimated to be saving about 360 GJ per farm, worth approximately $3200 per year.

CONCLUSION 3: Farms vary widely in intensity and distribution of energy use and in application of conservation methods. An individual energy management plan needs to be developed for each farm.

CONCLUSION 4: The participating farmers were very responsive to practical and economical energy management suggestions.

CONCLUSION 5: The installation of fuel meters and logs can create an 'energy awareness' which leads to better fuel energy management on a farm.

CONCLUSION 6: Major opportunities exist for liquid fuel savings by reduction in tillage operations, gear up - throttle down tractor operation, and use of more efficient cars and trucks, and in heating oil savings by up-grading of farm homes. These four measures alone could save up to $80,000,000 annually on Saskatchewan farms.

CONCLUSION 7: As fuel use is decreasing, indirect energy use as fertilizer, particularly nitrogen fertilizer, is increasing on Saskatchewan farms. FEMP farms used as much energy as fertilizer as they used as liquid fuels for farm production. These results suggest that efficient use of fertilizers, and use of renewable sources of nitrogen fertilizer, i.e., legumes, should have considerable emphasis in farm energy management.

CONCLUSION 8: Known methods of improving the efficiency of fertilizer use, such as deep banding, would have an economic impact (income gain) similar to the fuel savings mentioned in 6. The effect would be that of a productivity gain (i.e. more grain per kilogram of nitrogen fertilizer) rather than a fertilizer saving. Nonetheless, the increased income (income from higher yield minus cost of fertilizer) could be a powerful incentive to adopt the more fertilizer efficient deep banding technique.

CONCLUSION 9: Widespread application of the 'stubbled-in' minimum tillage method of growing winter wheat could have an economic impact (income gain) of about $250,000,000 annually. A third less fuel is required to grow a tonne of winter wheat by this new technology than to grow spring wheat by more conventional techniques.

CONCLUSION 10: Other methods being developed to improve fertilizer efficiency (variable rate application, for example) and to improve legume green manure cropping systems, could have substantial economic benefits in the near future.

CONCLUSION 11: The program has provided considerable new information on energy use and distribution on Saskatchewan farms. Transportation (cars and trucks) used 42% of the liquid fuels on these farms, emphasizing the importance of this sector in liquid fuel management.

CONCLUSION 12: Technology transfer is well under way. Talks were given at a number of seminars throughout western Canada, and a number of articles have been published in the popular farm press.

CONCLUSION 13: Spin off benefits to the private sector have commenced. For example, a new technique for variable rate fertilizer application is under commercial development by several private companies in Saskatoon.

8. RECOMMENDATIONS

RECOMMENDATION 1: Increased emphasis needs to be placed in future on technology transfer so that the dollar and energy savings projected in Section 4 can become realities. Use of fuel meters and recording logs should be included in this technology transfer process.

RECOMMENDATION 2: Continued emphasis needs to be placed on obtaining good case study examples of energy conservation actions. These provide the data for technology transfer by successful example.

RECOMMENDATION 3: Successful technology transfer will require involvement of the Extension Service of Saskatchewan Agriculture and the private sector.

RECOMMENDATION 4: An incentive program to encourage energy conservation on farms should be developed.

9. SUPPLEMENTAL REPORTS

Farm Energy Management Program — Year 1 Report. SRC Technical Report No. C-711-5-B-82.

Farm Energy Management Program — Year 2 Report. SRC Publication No. C-711-7-E-83.

Farm Energy Management Program — Year 3 Background Report. SRC Publication No. R-711-3-B-84.

Variable Rate Fertilizer Technology. SRC Publication No. R-812-2-E-84.

Economics of Changeover from Summerfallow Intensive Crop Systems to Low Tillage Crop Intensive Systems. SRC Publication No. R-812-1-E-84.

Conservation Farming Bulletins. Saskatchewan Agriculture. (Vol. 1 available, several others in preparation.)

Gayton, D.U. Direct energy use and conservation potential on Saskatchewan straight grain farms. In Energex 82, Conference Proceedings, Vol. II, University of Saskatchewan, Regina, 1982, pp. 687-690.

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